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Nature and Neurodevelopment: Differences in Brain Volume by Residential Exposure to Greenness

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A growing body of epidemiological studies have found associations between proximity to vegetated green areas ("greenspace") and multiple measures of good health.[1] Now researchers have examined how a child's exposure to greenspace may affect the development of his or her brain structure. A study in *Environmental Health Perspectives* reports changes in volume of both gray and white matter in association with lifelong residential exposure to greenness.[2] Further, the areas of the brain associated with greenness exposure in the study were also associated with cognitive function.

The study was led by Payam Dadvand, an assistant professor of epidemiology at the Barcelona Institute for Global Health. The investigators used a subset of 253 schoolchildren aged 7–9 years from the Brain Development and Air Pollution Ultrafine Particles in School Children (BREATHE) project.[3] To quantify lifelong exposure to greenness, the researchers used a measure known as the normalized difference vegetation index (NDVI) averaged across a buffer of 100 meters around each child's residence(s) since birth. The NDVI is based on remotely sensed data on the density of vegetation in a given area.

To quantify differences in brain volume for areas of white and gray matter, three-dimensional magnetic resonance imaging (MRI) results were compared among children with varying degrees of exposure to greenness. In one substudy, the investigators identified brain regions with a degree of volume that was associated with scores on computerized tests of cognitive function. A second substudy looked for overlaps between the brain areas associated with lifelong greenness exposure and the cognitive tests.

"We quantified the amount of greenness around the residential address of each child from birth to the time we did the brain imaging, and we saw that [a relatively greater] amount of greenness is associated with increased volume in some parts of the brain," says Dadvand. "These increases in volume were associated with better cognitive function, ascertained through computerized cognitive tests, and in time, overlapped, partly, with parts of the brain associated with cognitive function." But, he adds, it is important to focus not on specific areas but on the overall pattern.

Adjustment for neighborhood socioeconomic status and maternal education reduced the sizes of the brain areas that were significantly associated with greenness, with maternal education being the most influential factor. Some areas were no longer significantly associated with greenness after adjustment, although several did remain significant. These included areas mapped to gray matter in the right prefrontal cortex and the right premotor cortex and to

The NDVI is used in many studies of greenness to quantify the presence and density of vegetation in specific geographic areas. However, the index provides no information on the nature of the greenspace, whether it is accessible, or how it is used. Image: © Lee Adlaf/Shutterstock.

white matter in both hemispheres of the cerebellum. Gray matter is associated with higher-level thinking and processing, whereas white matter controls the autonomic nervous system and transmits information from the body to the gray matter.

"The measures of MRIs and lifetime exposure to residential greenness make this study quite innovative," says Peter James, an assistant professor of population medicine at Harvard Medical School and Harvard Pilgrim Health Care Institute, who was not involved in the study. "Although the mechanisms are still unclear, this study provides evidence that living near nature may contribute to brain development. However, there are some limitations to this analysis."

One limitation is that the NDVI does not incorporate the quality of the vegetation—for example, it provides no information on species type or whether vegetation occurs in, say, a park versus an overgrown vacant lot. The study also does not give any indication of the children's interactions with the surrounding greenspace.

Although the study used just one NDVI image (from July 2012, a month that falls between Barcelona's maximally green seasons of spring and autumn), James says that it is unlikely that vegetation levels changed substantially over the few years of the children's lives. However, he notes the findings may not apply to children in other geographic areas, and it will be important to confirm them in other study populations.

The article refers to the biophilia hypothesis, first popularized by biologist E.O. Wilson, which states that exposure to nature is required for humans, especially children, to thrive.[4] Dadvand says that a physical and mental connection to nature is "quite important in the context of our urbanizing world in which more and more children are living in urban areas, where they often have limited access to greenspaces, and, at the same time, are more exposed to air pollution and noise, factors that might have detrimental effects on their brain development." Two of Dadvand's previous studies also assessed greenspace in relation to cognitive development and attentiveness in schoolchildren,[3,5] but this is the first to map brain structure changes.

Dadvand adds that with all the bad news associated with environmental epidemiology—air pollution, climate change, and so forth—he likes that emerging studies about greenspace possibly enhancing brain development and cognition are harbingers of good news.

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References

1. James P, Banay RF, Hart JE, Laden F. 2015. A review of the health benefits of greenness. Curr Epidemiol Rep 2(2):131–142, PMID: 26185745, https://doi.org/10.1007/s40471-015-0043-7.
2. Dadvand P, Pujol J, Macià D, Martínez-Vilavella G, Blanco-Hinojo L, Mortamais M, et al. 2018. The association between lifelong greenspace exposure and 3-dimensional brain magnetic resonance imaging in Barcelona schoolchildren. Environ Health Perspect 126(2):027012, PMID: 29504939, https://doi.org/10.1289/EHP1876.
3. Dadvand P, Nieuwenhuijsen MJ, Esnaola M, Forns J, Basagaña X, Alvarez-Pedrerol M, et al. 2015. Green spaces and cognitive development in primary schoolchildren. Proc Natl Acad Sci USA 112(26):7937–7942, PMID: 26080420, https://doi.org/10.1073/pnas.1503402112.
4. Kahn PH Jr. 1997. Developmental psychology and the biophilia hypothesis: children's affiliation with nature. Dev Rev 17(1):1–61, https://doi.org/10.1006/drev.1996.0430.
5. Dadvand P, Tischer C, Estarlich M, Llop S, Dalmau-Bueno A, López-Vicente M, et al. 2017. Lifelong residential exposure to green space and attention: a population-based prospective study. Environ Health Perspect 125(9):097016, PMID: 28934095, https://doi.org/10.1289/EHP694.